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Since its discovery in the 1960's the ^{178m2}Hf isomer has garnered high attention from both the basic and applied communities in nuclear science. It's combination of high spin (16^+), long half life (31 yrs), and high excitation energy (2.446 MeV) offer unique possibilities as an energy storage medium.

Interest in the isomer was rekindled beginning in 1999 when a series of publications began to appear from a group (referred to here as the "Texas collaboration") primarily based at the University of Texas, Dallas [1]. They reported observations that some of the stored energy could be released ("triggered") when the isomer was exposed to a fluence of photons in the energy range ~10 to ~60 keV. The implications of this observation are profound. Even though the claimed cross section for the process was ~ 7 orders of magnitude greater than would be predicted from the known systematics of photon absorption by nuclei in this mass range [2], such a highly efficient method for triggering the isomeric deexcitation immediately suggested applications utilizing the explosive or the controlled gradual energy release from a very compact source. The prospect of such applications has focused considerable interest on realizing the promise that is implicit in the reported observations.

However, two experiments performed by a group from ANL/LANL/LLNL at the Advanced Photon Source at Argonne (the "APS collaboration") reported negative results for the observation of any photon-triggered deexcitation of the ^{178m2}Hf isomer [3]. This has led to a continued controversy, where both sides have adamantly defended their observations. At this point an outsider has difficulty determining whether there is indeed a triggering effect that should be pursued energetically with substantial resources, or whether the phenomenon consists of overly optimistic interpretation of data.

The main points reported by the "Texas collaboration" are:

1. A series of experiments has been performed using different facilities and varying teams of collaborators. These experiments have consistently observed positive results for the photon-induced deexcitation of the ^{178m2}Hf isomer, showing enhancements of several percent in the decay rates of various gamma-ray lines in the known decay chain of this isomer.
2. For the first published measurement, with a dental x-ray machine, which had a continuous x-ray spectrum, the triggering x-rays were estimated to lie in the energy range between 20 and 60 keV.
3. Later experiments at the SPring-8 light source in Japan stepped a monochromator through a range of x-ray energies and showed enhancements in the decay rates for lines in the isomer decay chain. The "monochromatic" x-ray beams used had an energy width of 0.5 eV. Enhancements of a few percent in the isomer decay rate were found for x-ray beam energies that included the regions from 11.27 - 11.4 keV, 11.6 - 11.7 keV, and 9.56 - 9.63 keV. Within these regions, enhancements were observed over sub-regions that typically had energy widths of 50 to 100 eV.
4. In the SPring-8 data, a recent analysis [4] corroborated previous measurements (see Hyperfine Interactions publication cited in [1]) of a new gamma-ray line around 130 keV, a transition not seen in the normal decay of the isomer or in other studies of this nucleus. This is reported as a unique result of the "triggering" of the isomeric energy release. This

new line is measured to be in coincidence with a known 213-keV transition in the normal decay chain.

5. These latter experiments report that the energy release from the isomer, once triggered, is prompt and bypasses the 4-sec isomer.
6. Preliminary results from a recent experiment done by a team led by P. McDaniel are reported to have observed an average triggering signal that was 15% in excess of the natural decay rate, when ^{178m2}Hf was irradiated with photons from the LEXR facility [5].

The main points reported by the "APS collaboration" are:

1. Several measurements were carried out with a "white" photon beam from the Advanced Photon Source, with intensities ~5 orders of magnitude higher than those used in the first Texas experiment, in attempts to reproduce the reported results. None of these measurements showed a statistically significant enhancement of the decay rate.
2. These first measurements focused on trying to verify the "dental x-ray" experiment (x-ray range above 20 keV) with a relatively thick target. These APS measurements showed no enhanced decay rate within statistical errors. Cross section limits were set ~5 orders of magnitude lower than those reported by the Texas group. The measurements were focused on the population of the 4-sec isomer, since the first Texas results reported enhancements in the gamma rays that feed this isomer, but limits were also set for prompt, in-beam decay enhancement.
3. A second set of measurements used a thin Hf target to cover more sensitively the x-ray energy range below 20 keV, the regions reported to show triggering in the SPring-8 experiments conducted by the Texas group. While these measurements too were focused on populating the 4-sec isomer, spectra were also recorded during irradiation (with the x-ray beam "on"). No enhancement was seen in either prompt or delayed gamma-rays. The APS photon intensities on the target *per eV* were higher than from the SPring-8 monochromator, and the target was illuminated by all energies simultaneously. The limits are again orders of magnitude below the published results of the Texas group.
4. While no evidence was seen for the 130-keV transition reported, the APS experiment was not very sensitive to this gamma-ray line because of the absorbers that were in use.

The Texas group offers the following criticisms of the work of the APS collaboration:

1. The APS group, by focusing on the 4-sec isomer and the gamma-rays *after* irradiation, has missed the effect.
2. The very high photon flux in the APS experiment invalidates any in-beam results because of electronics problems.
3. The failure to see the 130-keV line is a further illustration of the problems in the APS measurements.
4. To quote from a talk presented by Dr. C. Collins to the HIP panel [4]:

   "The DOE/Argonne Work is without merit.

   Detectors are blind to the "new" gamma-line emitted from triggered isomers
   SR irradiation is NOT monochromatic and cannot be tuned.
   Time scale used in seconds when phenomena occur in picoseconds
   Flux levels are deep into saturation.
   Principals DO NOT maintain cognizance of current literature.

   Also note: Argonne is proving to be the only SR source at which isomer triggering cannot be done"

The APS group responds as follows:

1. Some of the APS measurements *were* indeed performed during the x-ray beam "on" periods. These were reported in the publications, but not emphasized, since the Texas group reported enhancement in several transitions that *must* feed the 4-sec isomer.

2. The x-ray flux was high, but the counting rates in the detectors were under control and dead time and pileup effects were monitored and under control.
3. Though several of the Texas experiments *have* reported positive results for the photon-induced deexcitation of the isomer, these reports have not been consistent in:
   a) the photon energy needed for the triggering deexcitation,
   b) the cross section for the deexcitation process, and
   c) the lines in the chain of gamma-rays that show enhancement.

   The cross-section limits from the APS experiments are 3-5 orders of magnitude below any of the claimed positive deexcitation paths.
4. It is true that, due to absorbers used to suppress scattered radiation from reaching the photon detectors, the APS experiments had poor sensitivity for detecting low-energy gamma rays such as the claimed 130-keV transition, but this transition *was* reported to be in coincidence with the 213 keV 4^{+}->2^{+} line from the ground-state band, and this line showed *no enhancement* at levels 4 orders of magnitude below the claimed triggering cross section for both the in-beam and delayed data.
5. Given that no details are currently available regarding McDaniel's unpublished preliminary results it is impossible for the APS collaboration to make an assessment of the data. The important physical quantity is not the percentage increase for the triggering signal but a cross section for the process. Once the results are presented more fully, a meaningful comparison may be possible.

Recommendation

Resolution of this controversy is critical for two important reasons. First, based on the claimed results for an efficient process to trigger the release of the stored nuclear energy of the isomer, the US Government is evaluating multi-million-dollar methods for the production of large quantities of ^{178m2}Hf. Second, and possibly more important, is the question of how US Government program managers receive and evaluate highly technical information on innovative, break-through science. The first deals with the potential waste of public funds, the second deals with the integrity of the scientific process and its impact on governmental decisions.

It is understandably difficult for program managers to assess highly specialized information from the broad scientific spectrum. However, some cases, and we believe this to be one, have sufficiently important implications that it becomes crucial to make the correct technical evaluation. Fortunately, in this current controversy all of the issues are in fact technical. And though program managers may or may not possess the required expertise to evaluate all of the claims, such experts are available to assist in this evaluation. The APS collaboration strongly urges that a panel of such experts be convened to advise the program offices on the scientific merits of this issue. To be credible to all sides of the controversy it is imperative that this panel be composed of knowledgeable scientists of the highest repute who are independent from, and impartial to, the contesting parties. We believe that a logical source from which to draw such panel members includes:

- Former Chairs of the American Physical Society Division of Nuclear Physics.
- Former winners of the Bonner Prize for Nuclear Physics
- Nuclear physicists who are members of the National Academy of Science
- Members of the JASON

References:

1. C.B. Collins et. al., Phys. Rev. Lett. **82**, 695 (1999), C.B. Collins et.al., Laser Phys. **9**, 8 (1999), C.B. Collins et.al., Phys Rev. C **61**, 054305 (2000), C.B. Collins et. al., Phys. At. Nucl. **63**, 2067 (2000), C.B. Collins et.al., Hyperfine Interact. **135**, 51 (2001), C.B. Collins et.al., Europhys. Lett. **57**, 677 (2002).

2. S. Olariu and A. Olariu, Phys. Rev. Lett. **84**, 2541 (2000), D.P. McNabb et.al., Phys Rev. Lett. **84**, 2542 (2000), P. von Neumann-Cosell and A. Richter, Phys. Rev. Lett. **84**, 2543 (2000).
3. I. Ahmad et.al., Phys. Rev. Lett. **87**, 072503 (2001), I. Ahmad et.al., Phys. Rev C **67**, 041305(R) (2003), D.S. Gemmell, AIP Conference Proceedings Volume 652, pp. 239-249, Jan. 24, 2003. 19th International Conference on x-ray and Inner-Shell Processes, Rome (Italy), 24-28 June 2002., J.A. Becker, et.al., Europhys. Lett. **61**, 721 (2003).
4. C.B. Collins, presented at HIP Panel Meeting DARPA/MTO May 15-16, Washington DC (2003)
5. P. McDaniel, presented at HIP Panel Meeting DARPA/MTO May 15-16, Washington DC (2003), and Private communication to M. Stickley, July 3, (2003).